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Memorandum

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FR: Chuck Purvis | W.I.: 12.2.10

RE: Estimation Results for Worker in Household Auto Ownership Model (WHHAO) with Accessibility

This memo describes the estimation results for an improved worker in household auto ownership choice model (WHHAO) that includes relative transit-to-highway accessibility as an input variable. The current version of the BAYCAST-90 WHHAO model is identical in specification except for the two additional accessibility variables included in the revised model.

The WHHAO model is a nested logit choice model with nine alternatives. The upper nest of the WHHAO model splits households by workers in household level (0, 1, 2+). The lower nest of WHHAO further splits households by vehicles available in household level (0, 1, 2+). In aggregate model application, the input households are market segmented by household income quartile, by zone-of-residence. The aggregate application output includes households by income quartile level (4) by workers in household level (3) by vehicle availability level (3), for 36 different household markets by travel analysis zone of residence.

1. Specification of Accessibility Variables for WHHAO Model

The first step in revising the WHHAO model is the development of various expressions related to transit and highway accessibility. The basic hypothesis is that the higher the transit accessibility from a neighborhood to other activities, the higher the probability of owning fewer vehicles. In other words, better transit is a substitution for owning more autos.

The 1965 and 1981 MTCFCAST travel demand model systems used a fairly cumbersome expression of accessibility, that is, the "ratio of the exponentiated utilities of the home-based work mode choice model, transit relative to drive alone." In shorthand, "REXP." This necessitates the use of the logsum variable from the work trip mode choice model as an input variable to the auto ownership model for the worker household model. (In contrast, there was no transit/auto accessibility variable in the model that predicted auto ownership level for non-working households).

Recent MTC research on incorporating accessibility in auto ownership models is included in a paper presented at the May 1998 ASCE Conference on Transportation, Land Use and Air Quality "Incorporating Land Use and Accessibility Variables in Travel Demand Models." This 1998 paper defined accessibility as "total employment within 30 minutes transit travel time, from zone-of-residence" and "total employment within 30 minutes drive alone travel time, from zone-of-residence" as test variables. This former variable (employment within 30 minutes transit travel time) was used by Portland in their 1989 model system.

The following accessibility variables were tested in this current research phase:

1. Total employment within 30 minutes transit travel time.
2. Total employment within 60 minutes transit travel time.
3. Ratio of total employment within 30 minutes transit travel time, relative to 30 minutes peak period drive alone travel time.
4. Ratio of total employment within 60 minutes transit travel time, relative to 60 minutes peak period drive alone travel time.
5. Weighted transit accessibility.
6. Ratio of weighted transit accessibility to weighted peak period drive alone accessibility.

The advantage of the weighted accessibility measures relative to the isochron measures is that the isochron measures, while intuitive and easy to follow, have arbitrary cut-off values such as 30 or 60 minutes. The weighted accessibility indices will change with small changes to transit and highway accessibility, and are not subject to these arbitrary isochron boundaries. As such, the isochron measures are used as a "straw man" accessibility measure in case WHHAO models based on the weighted accessibility measures are failures.

The first four variables, our "isochron" approach, uses the MTC BAYCAST program ACCMTX to read MINUTP transit and highway levels of service matrices and socio-economic zone databases to extract the relevant data. The outputs of ACCMTX are fairly intuitive: jobs within a specified travel time from a neighborhood (zone) of residence.

The weighted accessibility is similar (but not identical) to the accessibility analyses conducted on the 1998 Regional Transportation Plan (see C. Purvis memo of 6/24/98). The accessibility index used in the 1998 RTP analysis is basically an "inverse power" gravity model function, as follows:

$$A_{ik} = \sum_j TotalEmployment_j TravelTime_{ijk}^{-2.0}$$

The term "travel time between 'i' and 'j' by mode 'k' raised to the '-2.0' power" is essentially a gravity model friction factor. The friction factor between two zones, multiplied by the total employment at zone-of-attraction, then summarized by zone-of-residence, is an accessibility index. The higher the index, the more accessibility that neighborhood has to other neighborhoods' activities and opportunities by that means of transportation.

The current MTC trip distribution (gravity) models are hand-fitted friction factor "lookup tables" that have integer number friction factors associated with each travel time increment. For home-based work trips, these travel time increment range from one to 110 minutes.

Several models were estimated to match the form of the hand-fitted friction factors for composite home-based work trips. This includes an inverse power function model; a gamma function model; an exponential function model, and a modified exponential function model. These models are presented in Figures 1 and 2.

The following table summarizes the structure of the alternative friction factor models. These models are also shown in Figure 2.

Functional Form	Equation
Inverse Power Function	$FF_{HBW} = 300000 / (T_{ij})^{2.0}$
Gamma Function	$FF_{HBW} = 20000 * T_{ij} * \exp^{(-.14 * Tij)}$
Exponential Function	$FF_{HBW} = 250000 * \exp^{(-.12 * Tij)}$
Modified Exponential Function	$FF_{HBW} = 150000 * \exp^{(-.57 * (\ln(Tij)/1.11)\hat{}2)}$

The best fit model is the modified exponential function model, so I created a TP+ job script (Appendix A) that creates a set of AM peak period transit and drive alone accessibility indices by zone-of-residence. The following is a representation of the final accessibility formula used in our "weighted" transit and highway accessibility variables:

$$A_{ik} = \sum_j TotalEmployment_j \times 150000 \times \exp^{-0.57 \times \frac{\ln(Tij)^{2.0}}{1.11}}$$

This modified exponential equation is the same functional form as developed in Gävle, Sweden and as reported in Kanafani (1983). Note that for a travel time of 1.0 minute, the friction factor is 150000 (the natural log of 1.0 is zero, and EXP(0) = 1.0). (This modified exponential form is a non-linear regression model. This model was estimated using the MS-EXCEL add-in XLSTAT. These friction factor models are included in my EXCEL workbook "Friction Factor tests.xls".)

ArcView plots showing the 1990 weighted transit accessibility, and the 1990 ratio of transit-to-highway accessibility, using this new modified exponential friction factor, are shown in Figures 3 and 4. As with previous experiments, neighborhoods in San Francisco, Berkeley and Oakland show the highest transit accessibility compared to Bay Area suburbs.

The network planning package TP+ is used to extract an ASCII file containing zone-of-residence, weighted drive alone accessibility, and weighted transit accessibility. Data is for the AM peak period. For this model estimation work, 1990 base year network LOS data is used.

The master WHHAO model calibration file, the isochron accessibility file and the weighted accessibility file are then merged using PC-SAS (see Appendix B). SAS is used to produce a space-delimited ASCII file that is used in our logit estimation package ALOGIT. File format for the final WHHAO model calibration file is included as Appendix "D".

2. WHHAO Logit Model Estimation Results

An additional dozen WHHAO models were estimated as part of this project. All new models included one of the six accessibility measures discussed in the previous section. Parameters were estimated for just zero-vehicle households, or two new parameters for both zero-vehicle and single-vehicle households.

As with all logit model development projects, we first estimate a multinomial logit model with all but the nesting (theta) parameters. Then the parameter values from the multinomial logit models are used as seed coefficients for estimating the nested form of the specification.

The following table summarizes the multinomial logit specifications for the WHHAO model:

Model #	# of Coeff.	Final LL	Variable Added	Coeff. Value	t-stat on Coefficient	Which Utilities?
09W	37	-2806.2	-	-	-	-
12W	38	-2798.9	TOTTRN30	.3624E-5	(3.8)	AO=0
13W	39	-2794.2	TOTTRN30 TOTTRN30	.6172E-5 .3343E-5	(4.7) (3.0)	AO=0 AO=1
14W	39	-2794.7	TRN/HWY30 TRN/HWY30	4.709 2.459	(4.7) (3.0)	AO=0 AO=1
15W	38	-2800.3	TOTTRN60	.1229E-5	(3.4)	AO=0
16W	39	-2797.9	TOTTRN60 TOTTRN60	.1568E-5 .5229E-6	(3.4) (4.0)	AO=0 AO=1
17W	39	-2798.5	TRN/HWY60 TRN/HWY60	3.649 1.208	(3.9) (2.1)	AO=0 AO=1
18W	38	-2799.5	WGTACCTR	.7765E-6	(3.4)	AO=0
19W	39	-2794.4	WGTACCTR WGTACCTR	.1776E-5 .1183E-5	(4.1) (2.9)	AO=0 AO=1
20W	**39**	**-2793.4**	**WGTACCTR/HWY** **WGTACCTR/HWY**	**6.548** **3.756**	**(4.6)** **(3.0)**	**AO=0** **AO=1**
21W	33	-2796.9	WGTACCTR/HWY WGTACCTR/HWY	6.789 4.001	(5.3) (3.3)	AO=0 AO=1
22W	30	-2803.1	WGTACCTR/HWY WGTACCTR/HWY	6.725 3.885	(4.8) (3.1)	AO=0 AO=1
23W	29	-2808.5	WGTACCTR/HWY	3.639	(3.9)	AO=0

The model #9W is the base model used in the current BAYCAST system. All models that add accessibility variables are a statistically significant improvement over the base model #9W. Models #12W through #17W test the isochron methodology accessibility variables. The coefficients are in the right direction and magnitude, with the AO=0 coefficients higher than the AO=1 coefficients.

Models #18W through #20W were the first to use the weighted accessibility variables. All are excellent multinomial choice models and are statistical improvements over the MNL base model #9W.

My next step was to estimate a nested logit model using the best multinomial logit model, model #20W. The MNL model #20W has the ratio of weighted transit-to-highway accessibility in both AO=0 and AO=1 utilities, and is the best overall model with a final log likelihood index of 2793.4.

The nested logit model based on MNL model #20W did not converge after 300 iterations. The theta (nesting) parameters were unacceptable, with values above 1.0. (This is similar to my experience when preparing my 1998 ASCE paper: adding accessibility variables fouled up the nesting coefficients!)

The next stage was to explore other model specifications in hopes that the nesting parameters would be in the acceptable 0.0 to 1.0 range. First, model #21W was estimated by excluding six of the weakest variables in the piece-wise specification of household income and gross population density (note 33 model parameters instead of 39 model parameters in model #20W). The nested version of model #21W failed, though it did close in under 30 iterations. Model #22W was a further simplification, using straight gross population density instead of the piece-wise specification of density used in many previous models. The nested version of #22W also produced bad theta parameters. MNL model #23W is even a simpler specification, same as model #22W but excluding the accessibility variable for AO=1 utilities. The nested version was also a failure.

Since all of the freely estimated nested choice models were failures, we have also fallen back to constrain certain nesting parameters (thetas) to reasonable values. So, a nested version of MNL model #20W was estimated with the nesting parameter for non-working households constrained to 0.75. This model finally worked! The theta (nesting) parameters for this constrained version of model #20W yield the parameters: non-working households: 0.7500 (constrained); single-worker households: 0.4286 (5.2 t-statistic); and multi-worker households 0.1321 (15.5 t-statistic).

All of the coefficients for the nested model #20W were evaluated with respect to the MNL model #20W and the nested model #9W, and are reasonable in direction and magnitude. As such, we should accept the nested model #20W for aggregate adaptation into the BAYCAST model system.

The coefficients for the MNL and nested models #9W are summarized in Table 1. The coefficients for the accessibility-sensitive MNL and nested models #20W are summarized in Table 2. A matrix of coefficients for the final nested logit model #20W are shown in Table 3.

The ALOGIT setups to estimate the multinomial and nested forms of model #20W are included as Appendix C to this memo.

3. Next Steps

The next step in this process is to outline the specification for the aggregate application of the WHHAO nested model #20W in BAYCAST. I want to keep our older model application, so we should call the new BAYCAST program WHHAOX, for workers in household auto ownership model, with accessibility. This should be fairly easy for Pat Hackett to implement, since it has the same model specification as the existing model, but we're reading in an additional ASCII file (the output from TP+) and are adding two new coefficients.

When the new WHHAOX model application software is complete, I will want to re-validate this model for a 1990 base year. Then we should conduct some sensitivity tests using our future year networks. The big issue behind all of this work is: does this relative transit/highway accessibility variable have a significant impact on future year auto ownership forecasts?

Table 1
Specification of WHH/AO Multinomial and Nested Choice Models - Model #9W
1990 Bay Area Household Travel Survey,Single Day Sample

WHH=0	WHH=0	WHH=0	WHH=1	WHH=1	WHH=1	WHH=2+	WHH=2+	WHH=2+		Model #9W (MNL)		Model #9W (Nested)	
AO=0	AO=1	AO=2+	AO=0	AO=1	AO=2+	AO=0	AO=1	AO=2+	Variable	Beta	t-stat	Beta	t-stat
n									constant 1	0.9349	(1.4)	1.615	(1.4)
	n								constant 2	2.33	(3.8)	3.084	(2.6)
		n							constant 3	0.6962	(1.1)	1.679	(1.4)
			n						constant 4	0.2607	(0.4)	1.586	(1.2)
				n					constant 5	1.719	(2.9)	3.284	(2.5)
					n				constant 6	-0.4014	(0.6)	1.237	(0.9)
						n			constant 7	-1.851	(2.0)	-2.941	(2.8)
							n		constant 8	-0.3117	(0.5)	-0.7834	(1.1)
	n								Income-Leg 1	4.633E-02	(2.4)	3.956E-02	(2.1)
		n							Income-Leg 1	0.1000	(4.2)	0.0888	(3.6)
			n						Income-Leg 1	0.1093	(4.3)	0.2853	(2.4)
				n					Income-Leg 1	0.1671	(8.1)	0.3433	(3.0)
					n				Income-Leg 1	0.2139	(8.2)	0.3907	(3.3)
						n			Income-Leg 1	0.1267	(3.0)	0.9325	(1.7)
							n		Income-Leg 1	0.1729	(5.9)	0.9719	(1.8)
								n	Income-Leg 1	0.2418	(8.8)	1.0320	(1.9)
	n								Income-Leg 2	1.213E-02	(0.8)	9.989E-03	(0.6)
		n							Income-Leg 2	2.564E-02	(1.6)	2.268E-02	(1.4)
			n						Income-Leg 2	1.122E-02	(0.7)	4.776E-02	(1.4)
				n					Income-Leg 2	2.310E-02	(1.6)	5.624E-02	(1.7)
					n				Income-Leg 2	4.604E-02	(3.1)	7.682E-02	(2.4)
						n			Income-Leg 2	3.035E-02	(1.5)	0.2699	(1.6)
							n		Income-Leg 2	4.740E-02	(3.1)	0.2866	(1.7)
								n	Income-Leg 2	6.685E-02	(4.5)	0.3048	(1.8)
		n							HH Size	0.4119	(5.4)	0.3311	(3.8)
					n				HH Size	0.5893	(9.7)	0.5986	(8.9)
						n	n	n	HH Size	0.4688	(7.0)	1.3790	(2.4)
n			n			n			MFDU	0.5272	(2.8)	0.5662	(3.0)
		n			n			n	MFDU	-0.9346	(8.0)	-1.0700	(8.8)
n	n	n							SHPOP 62+	3.4230	(16.8)	4.5390	(2.9)
						n	n	n	SHPOP 62+	-2.5250	(7.3)	-12.1900	(1.7)
	n			n			n		GPOPD-Leg 1	-0.03546	(1.0)	-0.05354	(1.6)
		n			n			n	GPOPD-Leg 1	-0.05174	(1.4)	-0.07401	(2.2)
	n			n			n		GPOPD-Leg 2	-0.04837	(3.5)	-0.04987	(3.6)
		n			n			n	GPOPD-Leg 2	-0.10180	(6.4)	-0.11170	(6.9)
	n			n			n		GPOPD-Leg 3	-2.378E-02	(4.0)	-2.506E-02	(4.1)
		n			n			n	GPOPD-Leg 3	-2.380E-02	(2.7)	-2.724E-02	(2.9)
n	n	n							Theta - NWHH			0.7451	(3.0)
			n	n	n				Theta - SWHH			0.4477	(2.7)
						n	n	n	Theta - MWHH			0.1968	(1.8)
									Log Likelihood	-2806.2		-2780.5	
									Rho-Bar Square	0.403		0.4084	
									Convergence Error	1.09E-04		0.008305	

Table 2
Specification of WHH/AO Multinomial and Nested Choice Models - Model #20W
1990 Bay Area Household Travel Survey,Single Day Sample

WHH=0	WHH=0	WHH=0	WHH=1	WHH=1	WHH=1	WHH=2+	WHH=2+	WHH=2+		Model #20W (MNL)		Model #20W (Nested)	
AO=0	AO=1	AO=2+	AO=0	AO=1	AO=2+	AO=0	AO=1	AO=2+	Variable	Beta	t-stat	Beta	t-stat
n									constant 1	0.6498	(1.0)	1.244	(1.9)
	n								constant 2	2.149	(3.5)	2.785	(4.4)
		n							constant 3	0.678	(1.0)	1.496	(2.1)
			n						constant 4	-0.0506	(0.1)	1.488	(1.2)
				n					constant 5	1.539	(2.6)	3.231	(2.7)
					n				constant 6	-0.3903	(0.6)	1.285	(1.1)
						n			constant 7	-2.161	(2.3)	-3.2	(3.0)
							n		constant 8	-0.4893	(0.7)	-0.9556	(1.3)
	n								Income-Leg 1	4.553E-02	(2.4)	4.024E-02	(2.1)
		n							Income-Leg 1	0.09839	(4.1)	0.08918	(3.6)
			n						Income-Leg 1	0.1105	(4.4)	0.2987	(3.0)
				n					Income-Leg 1	0.1662	(8.1)	0.3566	(3.6)
					n				Income-Leg 1	0.2111	(8.0)	0.4037	(3.9)
						n			Income-Leg 1	0.1294	(3.0)	1.4130	(2.2)
							n		Income-Leg 1	0.1725	(5.9)	1.4510	(2.3)
								n	Income-Leg 1	0.2389	(8.6)	1.5060	(2.3)
	n								Income-Leg 2	1.268E-02	(0.8)	1.012E-02	(0.6)
		n							Income-Leg 2	2.691E-02	(1.7)	2.313E-02	(1.4)
			n						Income-Leg 2	9.568E-03	(0.6)	4.879E-02	(1.4)
				n					Income-Leg 2	2.383E-02	(1.6)	5.923E-02	(1.8)
					n				Income-Leg 2	4.738E-02	(3.2)	8.002E-02	(2.4)
						n			Income-Leg 2	2.966E-02	(1.5)	0.4186	(2.0)
							n		Income-Leg 2	4.804E-02	(3.1)	0.4356	(2.1)
								n	Income-Leg 2	6.826E-02	(4.7)	0.4546	(2.2)
		n							HH Size	0.4058	(5.3)	0.3214	(3.8)
					n				HH Size	0.5812	(9.5)	0.5929	(8.8)
						n	n	n	HH Size	0.4635	(6.9)	2.0110	(2.4)
n			n			n			MFDU	0.4666	(2.5)	0.4880	(2.6)
		n			n			n	MFDU	-0.9136	(7.8)	-1.0520	(8.6)
n	n	n							SHPOP 62+	3.4220	(16.8)	4.5310	(16.7)
						n	n	n	SHPOP 62+	-2.5190	(7.3)	-18.0600	(2.3)
	n			n			n		GPOPD-Leg 1	-0.03480	(1.0)	-0.05200	(1.7)
		n			n			n	GPOPD-Leg 1	-0.05055	(1.4)	-0.07205	(2.2)
	n			n			n		GPOPD-Leg 2	-0.03454	(2.3)	-0.03913	(2.8)
		n			n			n	GPOPD-Leg 2	-0.07209	(4.2)	-0.09052	(5.5)
	n			n			n		GPOPD-Leg 3	-0.01572	(2.4)	-0.01829	(2.8)
		n			n			n	GPOPD-Leg 3	-0.00642	(0.6)	-0.01508	(1.6)
n	n	n							Theta - NWHH			*0.7500*	*(0.0)*
			n	n	n				Theta - SWHH			0.4286	(5.2)
						n	n	n	Theta - MWHH			0.1321	(15.5)
n			n			n			Trn-Hwy-Access	6.548	(4.6)	4.7320	(4.2)
	n			n			n		Trn-Hwy-Access	3.756	(3.0)	2.3610	(2.2)
									Log Likelihood	-2793.5		-2770.8	
									Rho-Bar Square	0.4057		0.4105	

Table corrected 7/25/00

Table 3
Review of Model #9W (Nested) Coefficients - Matrix Format

Income - Leg 1

		AO= 0	1	2+
WHH=	0	0.0	0.03956	0.08881
	1	0.2853	0.3433	0.3907
	2+	0.9325	0.9719	1.032

Gross Pop. Density - Leg 1

		AO= 0	1	2+
WHH=	0	0.0	-0.0535	-0.074
	1	0.0	-0.0535	-0.074
	2+	0.0	-0.0535	-0.074

Income - Leg 2

		AO= 0	1	2+
WHH=	0	0.0	0.00998	0.02268
	1	0.04776	0.05624	0.07682
	2+	0.2699	0.2866	0.3048

Gross Pop. Density - Leg 2

		AO= 0	1	2+
WHH=	0	0.0	-0.0478	-0.1117
	1	0.0	-0.0478	-0.1117
	2+	0.0	-0.0478	-0.1117

Household Size (PHH)

		AO= 0	1	2+
WHH=	0	0.0	0.0	0.3311
	1	0.0	0.0	0.5986
	2+	1.379	1.379	1.379

Gross Pop. Density - Leg 3

		AO= 0	1	2+
WHH=	0	0.0	-0.02506	-0.02724
	1	0.0	-0.02506	-0.02724
	2+	0.0	-0.02506	-0.02724

Multi-Family Dwelling Unit (MFDU) Dummy

		AO= 0	1	2+
WHH=	0	0.5662	0.0	-1.07
	1	0.5662	0.0	-1.07
	2+	0.5662	0.0	-1.07

Share of Population Age 62+

		AO= 0	1	2+
WHH=	0	4.539	4.539	4.539
	1	0.0	0.0	0.0
	2+	-12.19	-12.2	-12.19

Table 3
Review of Model #20W (Nested) Coefficients - Matrix Format

Income - Leg 1

		AO= 0	1	2+
WHH=	0	0.0	0.04024	0.08918
	1	0.2987	0.3566	0.4037
	2+	1.413	1.451	1.506

Gross Pop. Density - Leg 1

		AO= 0	1	2+
WHH=	0	0.0	-0.052	-0.07205
	1	0.0	-0.052	-0.07205
	2+	0.0	-0.052	-0.07205

Income - Leg 2

		AO= 0	1	2+
WHH=	0	0.00	0.01012	0.02313
	1	0.04879	0.05923	0.08002
	2+	0.4186	0.4356	0.4546

Gross Pop. Density - Leg 2

		AO= 0	1	2+
WHH=	0	0.0	-0.03913	-0.09052
	1	0.0	-0.03913	-0.09052
	2+	0.0	-0.03913	-0.09052

Household Size (PHH)

		AO= 0	1	2+
WHH=	0	0.0	0.0	0.3214
	1	0.0	0.0	0.5929
	2+	2.011	2.011	2.011

Gross Pop. Density - Leg 3

		AO= 0	1	2+
WHH=	0	0.0	-0.01829	-0.01508
	1	0.0	-0.01829	-0.01508
	2+	0.0	-0.01829	-0.01508

Multi-Family Dwelling Unit (MFDU) Dummy

		AO= 0	1	2+
WHH=	0	0.488	0.0	-1.052
	1	0.488	0.0	-1.052
	2+	0.488	0.0	-1.052

Share of Population Age 62+

		AO= 0	1	2+
WHH=	0	4.531	4.531	4.531
	1	0.0	0.0	0.0
	2+	-18.06	-18.06	-18.06

Table A.3
Sample Calculation of Utilities in Nested WHH/AO Choice Model - Model #9W

Sample Household		**Sample Household Predicted Choices**				
Income	**$45,000**		**AO=0**	**AO=1**	**AO=2+**	**Total**
HH Size	**3**	**WHH=0**	**1.2%**	**3.2%**	**2.2%**	**6.5%**
MFDU	**0**	**WHH=1**	**3.5%**	**18.7%**	**16.8%**	**39.0%**
SHpop62P	**33.3%**	**WHH=2+**	**2.0%**	**12.2%**	**40.4%**	**54.5%**
GPOPD	**35.0**	**Total**	**6.7%**	**34.0%**	**59.3%**	**100.0%**

Alternative	Utility	exp(Utility)	Sum(exp(Utility))	P(AO|WHH)	P(AO,WHH)
whh=0, ao=0	3.12649	2.279E+01	1.271E+02	0.179	0.012
whh=0, ao=1	4.12617	6.194E+01	1.271E+02	0.487	0.032
whh=0, ao=2+	3.74734	4.241E+01	1.271E+02	0.334	0.022
whh=1, ao=0	9.67370	1.589E+04	1.745E+05	0.091	0.035
whh=1, ao=1	11.33320	8.355E+04	1.745E+05	0.479	0.187
whh=1, ao=2+	11.22640	7.509E+04	1.745E+05	0.430	0.168
whh=2+, ao=0	25.84723	1.680E+11	4.633E+12	0.036	0.020
whh=2+, ao=1	27.66573	1.035E+12	4.633E+12	0.223	0.122
whh=2+, ao=2+	28.86343	3.429E+12	4.633E+12	0.740	0.404

	LS	Theta	Theta * LS	exp(Theta * LS)	P(WHH)
Logsum(NWHH)	4.8453	0.7451	3.6102	36.975	0.065
Logsum(SWHH)	12.0699	0.4477	5.4037	222.222	0.390
Logsum(MWHH)	29.1642	0.1968	5.7395	310.912	0.545
				570.109	

APPENDIX A.
TP+ Job Script to Extract Weighted Transit and Drive Alone Accessibility Indices

```
;***************************************************************************************
;*   c:\tptest\access\wgtd-access1.job
;*   Create weighted accessibility measures for
;*   transit and highway networks, by zone-of-residence
;*   for possible inclusion in WHHAO model & use in MTC Accessibility Analyses
;*
;*   Note: the file peaktime.bin was created from the MINUTP job setup:
;*     c:\rval90\netlos\copylos.set.   The file peaktime.bin is a MINUTP
;*     merged matrix dataset with tables: 1) DA distance (xx.xx miles);
;*     2) DA time (xx.x minutes); 3) transit (AO=1+) (xx.xx minutes)
;*
;*        -- February 22, 2000 --
;***************************************************************************************
run pgm=matrix
  id=Develop Weighted Transit & Highway Accessibility -- 1990
  parameters zones=1099

  filei mati[1]=c:\rval90\netlos\peaktime.bin          ; read in 3-table LOS file

  fileo mato[1]=c:\tptest\access\testx6.bin,           ; write out matrices for checking
        mo=1-6,name=datime,trtime,ff_da,ff_tr,wgtdacc_da,wgtacc_tr

  filei zdati[1]=c:\rval90\zdata\zcalib90.dat,         ; read in Master zonal database
     z=1-5,totemp=138-143

  mw[1]=mi.1.2       ; work matrix 1 is peak drive alone time (xx.x minutes)
  mw[2]=mi.1.3       ; work matrix 2 is peak transit time (xx.xx minutes)

  mw[1]=mw[1]/10.    ; convert DA time to real minutes with explicit decimal
  mw[2]=mw[2]/100.   ; convert TR time to real minutes with explicit decimal

  jloop
    if (mw[2]==0.00)       ; if transit time is zero (unconnected) then reset the
      mw[2]=1440.00        ; transit time to 1440.00 minutes (all day long!)
    endif
  endjloop                 ; all drive alone times are non-zero, so no resetting required.

  ;* The following formula is a calibrated nonlinear model, fitted to MTC's
  ;* hand-calibrated friction factors. This form of the nonlinear model is
  ;* similar to the Gavle, Sweden (1964) model reported in Kanafani (1983).

  mw[3]=150000*exp(-0.57*(ln(mw[1])/1.11)^2)    ; HBW friction factor, DA times
  mw[4]=150000*exp(-0.57*(ln(mw[2])/1.11)^2)    ; HBW friction factor, TR times

  ;  examples of other friction factors....
  ;  mw[3]=mw[1]^-2.0                           ; simpler friction factor, DA times
  ;  mw[4]=mw[2]^-2.0                           ; simpler friction factor, TR times

  ;* Multiply the zone-of-work total employment by each i-j friction factor,
  ;* then scale by 0.001 to get the product of TOTEMPj * f(TTij)

  mw[5]=totemp[j]*mw[3]*0.001                   ; DA Accessibility, i-j matrix
  mw[6]=totemp[j]*mw[4]*0.001                   ; TR Accessibility, i-j matrix

  report marginrec=t,form=0,list=j,c5,c6,
     file=c:\tptest\access\zaccess.dat         ; Output Accessibility "Trip Ends"
                                                   ; in trip end ASCII file....

  ;*  note that "c5" is the rowsum (production totals) for work matrix 5,
  ;*  For accessibility by zone-of-residence, use the variables:
  ;*     c5 = Weighted Drive Alone Accessibility
  ;*     c6 = Weighted Transit Accessibility

endrun
;***********************************************************************************
```

APPENDIX B
PC-SAS job setup to assemble WHHAO model calibration file

```
*******************************************************************;
**   whhaao-access.sas                                            ;
**  Add additional, accessibility variables to WHHAO master logit  ;
**    calibration file ...                                        ;
**  TOTEMP within 30, 60 minutes travel time (transit, drive alone);
**  Weighted Accessibility (TOTEMP) by transit, drive alone       ;
**                                                                ;
**  Note that the output ASCII file is a space-delimited file     ;
**   for input to ALOGIT....                                      ;
**                                                                ;
**         -- February 22, 2000 --                                ;
*******************************************************************;
options pageno=1;
filename masterao 'c:\modeldev\whh_ao\hhcalib1.dat';
filename accessdb 'c:\rval90\access\accmtx90.dat';
filename wgtdacc  'c:\tptest\access\zaccess.dat';
filename mastera3 'c:\modeldev\whh_ao\hhcalib3.dat';
********************************************************************;
data ao1; infile masterao;
  input id autos vehg trucks bikes hhsize hhsize5 hhsizeg age
        agehead lifecyc income incomei incomeq incomeqi incval incvali
        hhfactor male female driver tenure2 mopeds mcycles county sd
        z1099 empres gempdi nempdi gpopdi npopdi gresdi nresdi whhg
        building shpop62p shpop65p shpop75p whh_ao;
********************************************************************;
data access1; infile accessdb;
  input z1099 1-4 rethwy30 5-11 serhwy30 12-18 tothwy30 19-25
        ciahwy30 26-32 rethwy60 33-39 serhwy60 40-46 tothwy60 47-53
        ciahwy60 54-60 rettrn30 61-67 sertrn30 68-74 tottrn30 75-81
        ciatrn30 82-88 rettrn60 89-95 sertrn60 96-102 tottrn60 103-109
        ciatrn60 110-116;
*********************************************************************;
data access2; infile wgtdacc;
  input z1099 wgtaccda wgtacctr;
*********************************************************************;
proc sort data=ao1; by z1099;
proc sort data=access1; by z1099;
proc sort data=access2; by z1099;
*********************************************************************;
data whhao2; merge ao1 access1 access2; by z1099;
  if id=. then delete;
*********************************************************************;
proc sort data=whhao2; by id;
*********************************************************************;
data _null_; set whhao2;
  file mastera3;
  put id autos vehg trucks bikes hhsize hhsize5 hhsizeg age
        agehead lifecyc income incomei incomeq incomeqi incval incvali
        hhfactor male female driver tenure2 mopeds mcycles county sd
        z1099 empres gempdi nempdi gpopdi npopdi gresdi nresdi whhg
        building shpop62p shpop65p shpop75p whh_ao
        tothwy30 tothwy60 tottrn30 tottrn60
        wgtaccda wgtacctr;
*********************************************************************;
run;
```

APPENDIX C
ALOGIT Job Setups to Estimate Multinomial and Nested Logit Model #20W

```
Estimate Worker/Auto Ownership MNL Choice Model - weighted - Model #20
---------------------------------------------------------------------------
--   c:\modeldev\whhaoacc\MOD20w.BIN
--   Estimate Nine-Alternative Workers/Household Autos/Household
--     Multinomial Logit Choice Model
--  ** Includes Accessibility Variables . . .
--          -- February 22, 2000 --
---------------------------------------------------------------------------
--  Control Lines....
--  Non-availability of choice
--     Single-Person Households cannot choose Multi-Worker HHs
NONAV 7,101 8,101 9,101
STATS 1 0 50
STOP 10 3 0.0100
END
--------------------------------------------------------------------------
--   Coefficient Labels
01 Constant1
02 Constant2
03 Constant3
04 Constant4
05 Constant5
06 Constant6
07 Constant7
08 Constant8
09 Income1_N1
10 Income1_N2
11 Income1_S0
12 Income1_S1
13 Income1_S2
14 Income1_M0
15 Income1_M1
16 Income1_M2
17 Income2_N1
18 Income2_N2
19 Income2_S0
20 Income2_S1
21 Income2_S2
22 Income2_M0
23 Income2_M1
24 Income2_M2
25 PHH_NWHHA2
26 PHH_SWHHA2
27 PHH_MWHH
28 MFDU_AO=0
29 MFDU_AO=2+
30 SHPOP62P_N
31 SHPOP62P_M
32 GPOPD1_AO1
33 GPOPD1_AO2
34 GPOPD2_AO1
35 GPOPD2_AO2
36 GPOPD3_AO1
37 GPOPD3_AO2
38 trnhwywaA0
39 trnhwywaA1
----------------------------------------------------------------------
--   Alternative choice, weights and exclusions....
CHOICE = D040
ID = D001
D101 = ifgt(d006,1)
WGT = D018/1000.
WEIGHT = WGT
-  Exclude if Income is refused or not answered...
-  EXCLUDE=IFEQ(D009,88) OR IFEQ(D009,99)
--------------------------------------------------------------------------
-   Calculate extra variables desired in model estimation....
INCOME = D017/1000.
```

```
INCOME1= MIN(INCOME,25)
INCOME2= MAX(0,MIN(INCOME-25,50))
INCOME3= MAX(0,INCOME-75)
PHH    = D006
PHH2   = D006 * D006
PHH3   = D006 * D006 * D006
GPOPD  = D031
-GPOPD2 = D031 * D031
-GPOPD3 = D031 * D031 * D031
GPOPD1 = MIN(D031,10)
GPOPD2 = MAX(0,MIN(D031-10,20))
GPOPD3 = MAX(0,D031-30)
-GRESD1 = MIN(D033,3)
-GRESD2 = MAX(0,MIN(D033-3,7))
-GRESD3 = MAX(0,D033-10)
MFDU    = ifgt(d036,1)
SHPOP62P= D037
SHPOP65P= D038
SHPOP75P= D039
tothwy30= d041
tothwy60= d042
tottrn30= d043
tottrn60= d044
wgtaccda= d045
wgtacctr= d046
trnhwy30= d043/d041
trnhwy60= d044/d042
trnhwywa= d046/d045
-------------------------------------------------------------------------
-   Describe the utility functions...

-  WHH=0, AO=0 Utility
UTIL01 = BETA01 + BETA25*PHH     + BETA28*MFDU     + BETA30*SHPOP62P
                + beta38*trnhwywa

-  WHH=0, AO=1 Utility
UTIL02 = BETA02 + BETA09*INCOME1 + BETA17*INCOME2
                + BETA30*SHPOP62P
                + BETA32*GPOPD1 + BETA34*GPOPD2 + BETA36*GPOPD3
                + BETA39*trnhwywa

-  WHH=0, AO=2 Utility
UTIL03 = BETA03 + BETA10*INCOME1 + BETA18*INCOME2
                + BETA25*PHH     + BETA29*MFDU    + BETA30*SHPOP62P
                + BETA33*GPOPD1  + BETA35*GPOPD2  + BETA37*GPOPD3

-  WHH=1, AO=0 Utility
UTIL04 = BETA04 + BETA11*INCOME1 + BETA19*INCOME2
                + BETA28*MFDU
                + beta38*trnhwywa

-  WHH=1, AO=1 Utility
UTIL05 = BETA05 + BETA12*INCOME1 + BETA20*INCOME2
                + BETA32*GPOPD1 + BETA34*GPOPD2 + BETA36*GPOPD3
                + BETA39*trnhwywa

-  WHH=1, AO=2+Utility
UTIL06 = BETA06 + BETA13*INCOME1 + BETA21*INCOME2
                + BETA26*PHH     + BETA29*MFDU
                + BETA33*GPOPD1  + BETA35*GPOPD2 + BETA37*GPOPD3

-  WHH=2, AO=0 Utility
UTIL07 = BETA07 + BETA14*INCOME1 + BETA22*INCOME2
                + BETA27*PHH     + BETA28*MFDU
                + BETA31*SHPOP62P
                + beta38*trnhwywa

-  WHH=2, AO=1 Utility
UTIL08 = BETA08 + BETA15*INCOME1 + BETA23*INCOME2
```

```
                + BETA27*PHH
                + BETA31*SHPOP62P
                + BETA32*GPOPD1 + BETA34*GPOPD2 + BETA36*GPOPD3
                + BETA39*trnhwywa

-  WHH=2, AO=2+Utility
UTIL09 =          BETA16*INCOME1 + BETA24*INCOME2
                + BETA27*PHH     + BETA29*MFDU
                + BETA31*SHPOP62P
                + BETA33*GPOPD1  + BETA35*GPOPD2 + BETA37*GPOPD3

*******************************************************************


- Nested Workers/HH Autos/HH Choice Model -- SF Bay Area
--------------------------------------------------------------------
-  c:\modeldev\whhaoacc\nest004.ein
-  Estimate Nested WHH-AO Choice Model -- Based on MNL Model #20W
-     -- February 23, 2000 --
-  run nested with a maximum of 300 additional iterations...
-  START WITH SEED VALUES FOR THE THETAS....
--------------------------------------------------------------------
-  Standard three-trunk tree for WHH/AO Nested Choice Model....
-    U(NWHHAO0,NWHHAO1,NWHHAO2); U(SWHHAO0,SWHHAO1,SWHHAO2);
-    U(MWHHAO0,MWHHAO1,MWHHAO3)
-
TREE 10 10 10 11 11 11 12 12 12 99 99 99
THETA 9*0 110 111 112
STOP 300 3 .01000
END
--------------------------------------------------------------------
110 Theta_NWHH C 0.7500
111 Theta_SWHH F 0.4477
112 Theta_MWHH F 0.1968
--------------------------------------------------------------------
-  The End
```